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# Comparison of associative recognition versus source recognition

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## HIGHLIGHTS

- Object pairs were encoded with two study contexts.
- MTL activity was found for associative and source recognition.
- Cortical activity differed between associative and source recognition.
- MTL is involved in concurrent retrieval of associative and source memories.

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ABSTRACT

The importance of the medial temporal lobe (MTL) for memory of arbitrary associations has been well established. However, the contribution of the MTL in concurrent retrieval of different classes of associations remains unclear. The present fMRI study investigated neural correlates of concurrent retrieval of associative and source memories. Participants studied a list of object pairs with two study tasks and judged the status and context of the pair during test. Associative retrieval was supported by neural activity in bilateral prefrontal cortex and left ventral occipito-temporal cortex, while source recognition was linked to activity in the right caudate. Both the hippocampus and MTL cortex showed retrieval activity for associative and source memory. Importantly, greater brain activity for successful associative recognition accompanied with successful source recognition was evident in left perirhinal and anterior hippocampal regions. These results indicate that the MTL is critical in the retrieval of different classes of associations.


## 1. Introduction

According to dual process models of recognition, episodic memory can be supported by recollection of contextual details of an event or by acontextual familiarity-based recognition of the event [1,2]. The contribution of these processes in recognition has often been investigated by comparing correct versus incorrect judgment of the item-item association (associative memory henceforth) [3,4] or correct versus incorrect judgment of the item-context association (source memory hereafter) [5,6]. Previous fMRI studies have indicated the distinction between recollection and familiarity by uncovering a recollection network where memory judgments accompanied by recollection tend to be disproportionally correlated with activity in the medial temporal lobe (MTL), posterior parietal cortex, and medial prefrontal cortex during retrieval [7,8].

Considering that both associative and source memories are supported by recollection from the perspective of the dual process account, it is reasonable to ask if a single neural network underlies both memories for associations. Influential theoretical accounts of recognition postulate equivalent memory representations and mechanisms for different associations [9,10]. Although previous fMRI studies have reported different cortical activity for associative and source memory during encoding [11,12], it is still plausible that both memories are engaged in the same recollection network for retrieval of a cohesive representation of arbitrary associations. It is currently unknown whether associative and source recognition would show dissociations during *retrieval*, as found with encoding. In order to examine whether associative memory and source memory require independent neural activity in any extent during retrieval, the direct comparison of retrieval between two memories could be informative.

The aims of the present study were to address (1) whether concurrent retrieval of associative and source memories for an event would be supported by activity in the single neural network for recollection, and/or (2) whether associative or source recognition would employ different neural activity for its own retrieval

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mechanism. As such, the present study compared retrieval of associative and source memories for a single event at the whole brain level. Participants studied a list of picture pairs depicting objects with two study tasks. Participants were then administered associative recognition (association of objects in the pair) and source recognition (association of the pair and study task) tests. With this procedure, we investigated the neural network for concurrent associative and source recognition.

## 2. Methods

### 2.1. Participants

Twenty volunteers participated in the experiment (18–27 years; 10 males). They were right-handed, native English speakers who reported no history of neurological or psychiatric illness. Volunteers gave informed consent prior to participation, and they were compensated for their participation. The experiment was approved by the University of Texas at Arlington and the University of Texas Southwestern Medical Center Institutional Review Boards. One participant was excluded from analysis due to incomplete data.

### 2.2. Materials

The stimuli were drawn from a pool of 383 picture pairs depicting objects (Supplementary Methods). A study list comprised a pseudorandom ordering of 270 unrelated picture pairs such that each pair appeared equally often in each task context and each item in a pair was presented equally often to the left and right of a fixation cross. The study list also contained 90 perceptual baseline trials consisting of an arrow pointing either to the left or right. A test list comprised 360 pairs. Among them, 180 were studied pairs presented in the same pairing as at study (intact pairs), 90 pairs comprised studied items from the same study task but had been re-paired from study (rearranged pairs), and 90 were new pairs. Both study and test lists were constrained such that no pair from the same task occurred more than three times consecutively and were separately constructed for each subject. An additional 23 pairs were used for practice.

### 2.3. Procedure

Participants were given instructions and practice prior to the experiment proper. The experiment consisted of a single study-test cycle. On each study trial, a white cross appeared on the screen (200 ms), followed by a task cue (500 ms) indicating the task to be performed on the upcoming pair: 'FIT' or 'COMMON' (Supplementary Figure 1). For the 'FIT' task cue, participants judged whether an item in the pair fit into the other item in the pair. For the 'COMMON' task cue, participants judged whether the two items could be put together perceptually (e.g., Can they be found in the same place?, Can they be in the same color?, etc.). A pair was then displayed for 3 s, with one picture presented to the left and the other to the right of the fixation cross. Participants indicated their corresponding task judgments by pressing a button using their right hand. For perceptual baseline trials, an arrow pointing either to the left or the right was displayed for 1.6 s, and participants were asked to press the button in the opposite direction of the arrowhead.

The test was administered approximately 3–5 min after the end of the study phase. For each test trial, a picture pair was displayed for 3.7 s. Participants were instructed to make one of five associative/source recognition responses indicating the status of the pair and the study task: (i) Intact/Fit: two items studied in the same pairing as study with the fit judgment, (ii) Intact/Common: two items studied in the same pairing as study with the common judgment, (iii) Rearranged/Fit: two studied items that had been paired with different items at study with the fit judgment, (iv) Rearranged/Common: two studied items that had been paired with different items at study with the common judgment, or (v) New: two unstudied items. Participants were instructed to respond with 'New' if they were unsure about the pair or task, or if they recognized only one item of the pair. Both study and test phases were held in the scanner.

### 2.4. fMRI scanning

A 3 T MR scanner equipped with a 32-channel head coil was used to acquire both $T_1$-weighted high-resolution anatomical images (MP-RAGE, $240 \times 240$ matrix, 1 mm$^3$, sagittal) and $T_2^*$-weighted echo-planar images (flip angle 70°, $80 \times 80$ matrix, FOV 24 cm, TR 2000 ms, TE 30 ms, SENSE factor 1.5) per volume. Each volume comprised 33 slices oriented parallel to the AC-PC line (3 mm$^3$, 1 mm gap, axial) acquired in a descending sequence. Imaging data from the test phase were acquired in two scan sessions comprising 340 volumes each. Five additional volumes were collected at the beginning of each session but were discarded to allow for $T_1$ equilibration. The 3.7 s SOA allowed an effective sampling rate of the hemodynamic response of approximately 2 Hz.

### 2.5. fMRI data analysis

Statistical Parametric Mapping (SPM8) was used for data preprocessing and statistical analyses. For each participant, functional images were spatially realigned to the mean image, time-corrected to the middle slice, reoriented, normalized to the MNI EPI template, and smoothed with an 8 mm full-width half-maximum Gaussian kernel. Each participant's anatomical scan was normalized to the MNI $T_1$ template and averaged to create an across-subjects anatomical mean image.

Statistical analysis was performed on the test phase data using a two-stage mixed effects model. Prior to model estimation, image time series were concatenated across runs. In the first stage, stimulus-elicited neural activity was modeled with 2 s boxcar functions. The event-related blood oxygen-level dependent (BOLD) response was modeled by convolving these boxcar functions with a canonical hemodynamic response function (HRF). In addition, six regressors were employed to model movement-related variance along with session regressors. Parameter estimates for events of interest were estimated for each subject using a General Linear Model. Non-sphericity of the error covariance was accommodated by an AR(1) model [13]. Linear contrasts were constructed for each subject and entered into second level tests.

For analysis of concurrent retrieval of associative and source memory, four events of interest were defined: 'associative hits-source hits' (accurately judged *intact* pairs with correct study task judgment), 'associative hits-source misses' (accurately judged *intact* pairs albeit with incorrect task judgment), 'associative misses-source hits' (intact pairs inaccurately identified as *rearranged* but with correct task judgment), and 'associative misses-source misses' (intact pairs inaccurately identified as *rearranged* with incorrect task judgment). Item misses and recognition judgments to rearranged and new pairs were separately modeled but not further analyzed. Events of no interest included trials with omitted or multiple responses.

For the analysis at the whole-brain level, a repeated measures $2 \times 2$ ANOVA (memory: associative vs. source, accuracy: hit vs. miss) was implemented in SPM to identify neural activity for retrieval of associative memory and source memory. Effects were thresholded at $p < .001$, uncorrected with a 5 voxel extent threshold. For significant interaction effects, pair-wise $t$-tests were conducted for follow-up tests on parameter estimates extracted from peak voxels to examine the pattern of differences contributing